

FBS 0107-082: A Symbiotic Binary in a Rare Prolonged Outburst?

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ABSTRACT

FBS0107-082 is an emission line object previously classified as a nova-like cataclysmic variable star. New optical spectroscopy shows very strong hydrogen Balmer lines, along with a nebular forbidden line spectrum and absorption features from an early-F photosphere. When combined with other IR and optical data from the literature, these data point to the object being a symbiotic nova seen in a prolonged outburst. Photometry on time scales of minutes, days, and years show only very weak variability.

Subject headings: Stars-binaries:symbiotic-stars:individual(FBS0107-082)

1. Introduction

FBS 0107-082 (also known as Cet 7, and designated FBS0107 in this paper) was found in the First Byurakan Survey (FBS) for objects with UV excesses. Based on spectra obtained with the 6-m telescope at the Special Astronomical Observatory, Kopylov et al. (1988) provided a preliminary classification as a nova-like (NL) cataclysmic variable (CV). FBS0107 was subsequently listed as a CV in SIMBAD and in the Downes, Webbink, & Shara (1997) CV catalog, but has received very little attention since the initial discovery paper. We obtained spectra of FBS0107 in 2005 as part of a survey for winds in NL CVs, finding that the spectrum resembles that of a symbiotic star or planetary nebulae. We have complemented these initial spectra with multi-epoch photometry and with an analysis of archival ESO spectra.

In this paper we report on our spectroscopic and photometric findings and discuss the most likely kinds of objects that fit these findings. The star appears to be an unusual symbiotic binary. Symbiotic stars (Kenyon 1986) have evidence for a hot component in the near UV plus a cool component in the near-IR. In most cases the hot component is judged to be a white dwarf or evolved subdwarf, and the companion to be an M giant with a strong wind. Nebular emission lines are produced by the action of the radiation field of the hot component on the surrounding plasma from the wind. Symbiotic stars are not a particularly homogeneous group and the evolutionary state of the hot component (e.g. subdwarf or white dwarf) is often uncertain. Our observations are not a perfect fit to the symbiotic classification, but this identification seems to best match the properties of FBS0107.

2. Data Acquisition and Reduction

2.1. Photometry

V-band photometry was obtained over a 1.5 month interval in 2005 on the 0.8-m telescope of Tenagra Observatory¹. There were typically 1-4 exposures on most clear nights, but on two nights we obtained nearly continuous coverage for several hours. These data were reduced using a custom pipeline consisting of IRAF² routines for detector calibrations, followed by the application of SExtractor³. The light curves were then generated using the incomplete ensemble photometry technique contained in Astrovar⁴. FBS0107 was also placed on the long-term monitoring program of the Indiana University (IU) 1.25-m autonomous telescope⁵ for ~ 16 months in 2007/2008. The useable data are comprised of 122 exposures on ~ 113 different nights. The 1.25-m data were also reduced using the IRAF/SExtractor/Astrovar pipeline. Table 1 is a log of our photometric data. Column 1 assigns a number to identify each data set, column 2 gives the UT dates, column 3 the telescope used, column 4 the exposure time in sec, column 5 the number of useable exposures, column 6 the duration of

¹<http://www.tenagraobservatories.com/>

²IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

³SExtractor is a source detection and photometry package described by Bertin and Arnouts 1996. It is available from <http://terapix.iap.fr/soft/sextractor/>.

⁴ASTROVAR is a custom Indiana University package based on the technique described in Honeycutt 1992, but with the addition of a graphical user interface.

⁵This facility is located 20 km north of Bloomington IN, in the Morgan-Monroe State Forest

the sequence, and column 7 the typical spacing of the exposures.

Both the Tenagra exposures and the IU 1.25-m exposures were compromised by various circumstances, and did not reach the desired (and expected) level of precision. The Tenagra calibration data is acquired automatically, with no user control of the process. In our case the twilight flats, acquired on most evenings, were very underexposed; we ended up using a median combination of all the twilight flats over the ~ 1.5 months of the FBS0107 Tenagra exposures. Furthermore the Tenagra bias levels were unstable, sometimes leading to negative sky counts. The IU 1.25-m data and calibrations were also acquired in unattended fashion, during commissioning of the telescope and detector systems. Few twilight flats were acquired, and the nightly dome flats gave poor results. Therefore we used median sky flats constructed from all the exposures on a given (or adjacent) night. Also, we had significant dark current from the thermoelectrically-cooled system that was in service on the IU 1.25-m at this time, which further degraded the S/N. Fortunately Astrovar has sufficient tools to evaluate errors that might result from these difficulties (such as non-linearity, or field errors), and Astrovar also robustly estimates external errors based on the repeatability of all constant stars in the field.

In the end the average error for stars with brightness similar to FBS0107 was ~ 0.02 mag for the Tenagra data and ~ 0.025 mag for the IU 1.25-m data. These errors are for differential magnitudes with respect to the ensemble. There are no secondary standards available for this field (although the AAVSO is in the process of establishing such standards) so we used USNO-B1 magnitudes⁶ to establish a somewhat crude, but nevertheless realistic, zeropoint. The average of the B2 and R2 USNO-B1.0 magnitudes for several stars near FBS0107 were compared to the Astrovar differential V magnitudes of those same stars, separately for the Tenagra and for the IU 1.25-m data, to find the correction from Astrovar magnitude to V. This process has a formal uncertainty of 0.06 (sdm) mag, but the zeropoint error could be as large as 0.15 mag considering possible systematic errors in USNO-B1.0, plus errors introduced by our averaging of B and R to estimate the V magnitude.

⁶The USNOFS Image and Catalogue Archive is operated by the United States Naval Observatory, Flagstaff Station (<http://www.nofs.navy.mil/data/fchpix/>).

2.2. Spectroscopy

Five spectra over ~ 1 hr were obtained in 2005 using MOS/Hydra multiple object spectrograph on the WIYN⁷ telescope. Grating 600 was used in first order, providing coverage $\sim 5300\text{--}8200\text{\AA}$. The “red” 2” fiber bundle was employed, yielding $\sim 3\text{\AA}$ resolution; numerous other fibers were used for sky subtraction. Also, a single spectrum was obtained in 2006 using the RC slit spectrograph on the Kitt Peak 4-m telescope⁸. Grating KPC-007 was used in first order, providing coverage $\sim 5600\text{--}7900\text{\AA}$ at $\sim 3\text{\AA}$ resolution. Finally, the archives of the ESO Observatory⁹ were found to contain spectra of FBS017 acquired during a single night in 2004 using the EFOSC-2 spectrograph on the 3.6-m telescope at La Silla. Eighteen spectra were available using grism #18, covering $\sim 4700\text{--}6700\text{\AA}$ along with 5 spectra using grism #7, with useable coverage $3700\text{--}5240\text{\AA}$. A 1” slit was used, and the instrument manual gives a resolution of 7.4\AA for these setups. However, we find that the narrowest emission lines in the FBS0107 spectra have FWHM $\sim 5\text{--}6\text{\AA}$. For detector calibrations we used standard IRAF procedures, and for spectral extractions and wavelength calibrations we used IRAF’s onedspec/twospec packages. No spectrophotometric calibrations were applied for any of the spectra, and the continua in the reduced WIYN and Mayall spectra were normalized to unity. Also, no corrections were made for telluric spectral features in the near-IR. Table 1 is a log of the spectrographic observations.

3. Analysis

3.1. Photometry

Figure 1 plots the results from the two nights of nearly continuous monitoring (Sets 1 and 2 in Table 1). The top plot appears to contain a small outburst of amplitude ~ 0.07 mag, while the bottom plot shows a decline of ~ 0.04 mag over 5 hours. The Astrovar light curves of several field stars of similar brightness to FBS0107 were examined and did not show such features. The features are therefore probably real, but since they barely exceed the errors in

⁷The WIYN Observatory is a joint facility of the University of Wisconsin-Madison, Indiana University, Yale University, and the National Optical Astronomy Observatory

⁸The Mayall 4-m telescope is at Kitt Peak National Observatory, a division of the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation

⁹ Based on observations made with the European Southern Observatory telescopes obtained from the ESO/ST-ECF Science Archive Facility.

the light curves we are reluctant to draw any conclusions from them. The variability over a night is smaller than expected from CV-like flickering from accretion.

Figure 2 shows the longer-term light curve of FBS0107. The top panel contains all the data in Sets 1, 2, and 3 of Table 1, while the middle and lower panels contain the data for the two observing seasons in Set 4. It seems clear from Figure 2 that there is no systematic long-term trend over these 4 years. Nevertheless the scatter generally exceeds the individual error bars by 3-4 \times , at least for the points having smaller errors. To further illustrate this effect, Figure 3 is like Figure 2 except that data points having errors >0.035 mag are excluded (these were obtained under partly cloudy conditions). Also, the two sequences over single nights have been averaged to one data point each for Figure 3. One can find in Figure 3 a number of instances of systematic drifts in both directions amounting to ~ 0.1 mag over 15-20 days.

There is an indication of much longer time-scale variability from the magnitudes in USNO-B1.0. The average of the B and R magnitudes in USNO-B1.0 for FBS0107 is 14.72 (epoch 1951-1954). This is 0.33 mag brighter than our average magnitude of 15.05 in 2005-2008. One might question this result because of the uncertain effect of averaging B and R to estimate V. However, the exercise is robust in the following sense: The magnitude differences between our Astrovar instrumental magnitudes and the B,R average for our secondary standards are consistent to within 0.1 mag (s.d.s.o.), whereas the similar magnitude difference of FBS0107 is off by 0.33 mag from the mean of the other field stars. In other words, if one tries to treat FBS0107 as a secondary standard, it deviates from the field stars by more than 3-sigma, probably because it is variable. FBS0107 has a B-R color that is similar to that of the secondary standards, so we conclude that FSB is now fainter by ~ 0.3 mag in V compared to when the Palomar plates were exposed ~ 55 years earlier.

To summarize the photometry, we find that FBS0107 is a variable, but a puny one. We see changes of a few hundredths of a mag during a night and perhaps 2-3 \times that amount over a few weeks, but with no systematic trends exceeding 0.05 mag over our 4 year interval of photometry. These variations do not exceed our observational errors by much, and we are therefore unable to characterize the changes very well. No flickering was detected, nor any indication of an eclipse.

3.2. Spectroscopy

No exposure-to-exposure changes were apparent in the line strengths of the reduced spectra from any given night. Furthermore we did not detect any radial velocity variations

during these sequences, to within $\sim \pm 10 \text{ km s}^{-1}$ for 5 WIYN spectra, and to within $\sim \pm 15 \text{ km s}^{-1}$ for the ESO spectral sequences. Therefore we median-combined the 5 WIYN spectra, the 18 ESO red spectra, and the 5 ESO blue spectra, for further analysis.

First we compare the WIYN and KPNO 4-m spectra. These are separated by 2 months but have similar resolutions and wavelength ranges. Figure 4 shows the average of the 5 WIYN spectra of FBS0107 along with an inset plot of the $H\alpha$ line on an expanded scale, while Figure 5 is a similar plot for the KPNO 4-m spectrum. In each case $H\alpha$ dominates the spectrum, seen at a rather spectacular $\gtrsim 50\times$ the continuum level, at this resolution. The $H\alpha$ line is steeper on the red side, with this asymmetry being more pronounced in the KPNO 4-m spectrum. The weaker lines are shown in Figures 6 and 7, for two adjacent spectral regions in common to the WIYN and the 4-m spectra. Except for higher S/N in the WIYN spectra (due to having combined 5 exposures), the pairs of spectra in Figures 6 and 7 (separated by 2 months) appear identical. Most of the lines are due to HeI and OI. There is one absorption feature near 7772\AA which we assign to OI.

Figure 8 shows the median-combined ESO spectra (both red and blue). The identifications of the strongest lines are given in Table 3, where the equivalent width measures (EW) have a typical error of $\sim \pm 0.5\text{\AA}$. The lines are mostly emission lines of Hydrogen and HeI, plus forbidden emission lines of oxygen and iron. We also see weak absorption features at Ca H/K and at NaD. The inset shows the Balmer discontinuity in strong absorption. In order to preserve information about the Balmer discontinuity, the continua of the ESO spectra have not been normalized to unity as was done for the WIYN and KPNO spectra. A broad emission feature near $6160\text{-}6170\text{\AA}$ in Figs. 6 and 8 is assigned to FeI 6164, likely blended with an unidentified contributor which increases the breadth.

4. Discussion

The 1984 spectrum of FBS0107 in Kopylov et al. (1988) covers the range $3240\text{-}5040\text{\AA}$ at a resolution of 4.5\AA . It shows narrow Balmer emission lines with a steep decrement. HeII 4686 is weak, but [OIII] 5959, 5007, and [FeII] are strong. The Balmer discontinuity is not apparent in the Kopylov et al. spectrum. Their detector response is apparently weak below 3650\AA but a Balmer discontinuity in emission can be ruled out. Overall, the 1984 spectrum appears very similar to the ESO 2004 spectrum, indicating little variability in the spectrum of the star over those 20 years.

We discuss below a number of kinds of emission line objects as candidates for the nature of FBS0107, noting the similarities and differences to the currently-known properties of

FBS0107. We begin with symbiotic stars.

4.1. Symbiotic systems

Symbiotic stars (Friedjung & Viotti 1982; Kenyon 1986; Allen 1988; Mikolajewska et al. 1988) are interacting binaries with orbital periods of hundreds of days, consisting of a late-type giant donor star transferring gas (generally via a wind) to a much hotter compact companion. The hot object appears to most often be a white dwarf or hot subdwarf, but may be a main sequence star or neutron star in some instances. The hot star photoionizes the wind, giving rise to a nebular spectrum with emission lines due to species such as H I, He I, He II, [O III], [Fe II], etc. Symbiotic stars are a rather heterogeneous group, and might better be considered as a common phenomenon rather than a particular configuration and/or evolutionary state. The FBS0107 emission lines seen in Kopylov et al. (1988) and in Figures 4-8 of this paper are generally consistent with those of a symbiotic star, albeit having somewhat lower ionization level than average. The Balmer decrement in FBS0107 is quite steep, as is often found in symbiotic stars. However, because our spectra are not on a flux scale we cannot reliably quantify the decrement.

Apart from the emission lines, the spectrum of FBS0107 differs significantly from that of a classical symbiotic star. In the near-IR, the spectra of symbiotic stars show features from the late type companion. This is typically an M giant, but can be as early as G5 (Belczyński et al. 2000); no such features are seen in FBS0107. The few absorption features we see in FBS0107 do not belong to a late-type star. Using the plots and tables in Jaschek & Jaschek (1995) for the variations of the EWs of absorption features with spectral type, we find the following constraints on the absorption line spectral class for FBS0107: $EW = 0.9\text{\AA}$ for Ca II 3934 is most consistent with A0-A5; $EW = \sim 0.5\text{\AA}$ for Na D is most consistent with A5-G5, and $EW = 1.2\text{\AA}$ for O I 7772 \AA is most consistent with A0-F0 III-I. (This O I line is strongly luminosity sensitive, reaching $EW \sim 2\text{\AA}$ in supergiants (Parsons 1964)). Overall the results show that a late A to early F photospheric absorption spectrum is present in FBS0107. Also, the Balmer continuum is in absorption in FBS0107. In nearly all other cases in which the Balmer discontinuity is visible in a symbiotic, the jump is part of the nebular spectrum and appears in emission (see the compilations of spectra of symbiotics in Allen (1983) and in Munari & Zwitter (2002)).

The Barbier & Chalonge system of spectrophotometric classification uses the parameter D to measure strength of the Balmer jump, where D is the log of the ratio of the fluxes on the red and blue sides of the discontinuity. From the spectrum in Figure 9 we measure $D = 0.30$. A convenient calibration of D with spectral type can be found in Golay (1974).

For giants, $D = 0.3$ corresponds to either B5 or F1, and F1 is consistent with our earlier deduction of a late A to early F spectrum in FBS0107.

We also note that two emission features at $\lambda\lambda 6825$ and $\lambda\lambda 7082$ are not present in our spectra. These two features are probably due to Raman scattering of OIII resonance lines by neutral hydrogen (Schmid 1989) and appear in most high excitation symbiotics. This distinction may not be compelling however, because FBS0107 has a quite low excitation emission line spectrum.

IR photometry can potentially be used to discriminate between symbiotic binaries and other sources such as planetary nebulae and CVs, as well as between S-type and D-type symbiotics. Using 2MASS photometry, Figure 9 is a plot of J-H vs H- K_s for CVs (Hoard et al. 2002), symbiotics (Phillips 2007), and PN (Ramos-Larios & Phillips 2005). We see that the location of FBS0107 falls firmly among the PN, not the symbiotics, mostly because the J-H color is bluer than for most symbiotics. Most symbiotics contain an M giant, which contributes to making the J-H color redder. If FBS0107 is a symbiotic, then either the M star is heavily dust-obscured in the optical, or the M star is otherwise hidden.

Proga, Mikolajewska & Kenyon (1994) found that the ratio of the strengths of the He I emission lines $\lambda 6678/\lambda 5876$ fall in the range 0.15-0.3 for D-type (dusty) symbiotics, and 0.3-2.0 for S-type, which is attributed to a systematic difference in densities for the line forming regions in the two types. This ratio is ~ 0.4 in FBS0107 (see Table 3). This value is an upper limit because there has been no correction for differential extinction between the wavelengths of the two lines. If FBS0107 is a symbiotic star, it appears that this ratio is consistent with either D or S-type.

The variability properties of FBS0107 seem consistent with FBS0107 being a symbiotic star, but offer no particular evidence in favor. The lack of detectable radial velocity variations is not surprising given the long orbital periods and relatively small amplitudes of the radial velocities in symbiotic binaries. The variability in the H α profile seen in FBS0107 is also common in symbiotic binaries, but not uniformly present. Likewise flickering (not seen in FBS0107) is common (Belczyński et al. 2000) but has not been reported for all symbiotics.

Finally, symbiotic stars are often associated with a resolved nebula. The raw long-slit KPNO 4-m spectra were carefully examined for any extension of the emission lines along the slit, with negative results. The forbidden lines in FBS0107 indicate that a nebular emission line emission region is present in FBS0107, but the angular size of the nebula must be quite small.

The emission line species seen in FBS0107 require photons with energies ~ 35 eV for ionization, which in turn requires temperatures of $\gtrsim 10^5$ °K. The early F star seen in the

spectrum cannot be the source of this ionizing radiation, instead requiring the presence of a white dwarf or hot subdwarf. In principle the F star could be the mass doner and supplier of the nebular gas (via a wind), but this would require considerable extension of the definitions and mechanisms of symbiotic binaries.

A substantial fraction of symbiotic binaries undergo outbursts lasting weeks to decades, with a brightness increase of 2-7 mag. These are thought to be due to thermonuclear burning of hydrogen in the white dwarf envelope, analogous to the outbursts of ordinary novae, but much slower. Like ordinary novae, these symbiotic novae often display a A-F absorption spectrum during the early outburst stages, due to an optically thick envelope that develops around the erupting star. AG Peg, RT Ser, and RR Tel (see discussions and refs in Kenyon 1986) are examples of symbiotic novae with A-F absorption line spectra at maximum. The outbursts can sometimes last for decades, and for more than a century in the case of AG Peg. In each of these three systems, near outburst maximum, the M star spectrum is not seen in the near-IR. Emission lines appear during the decline from maximum, with the emission lines evolving to higher excitation as the decline progresses. (The AG Peg emission lines also showed P Cygni profiles and multiple velocity components, behaviors similar to that of ordinary novae.) Our spectra of FBS0107 are mostly consistent with that of the three symbiotic nova mentioned above, as displayed during the early portion of the decline from maximum. At this stage they have retained some of the absorption lines from near maximum, and have developed a relatively low excitation emission line spectrum, prior to the development of high-excitation emission lines and the emergence of the spectrum of the M star during late decline. All three of the symbiotic novae mentioned above showed the Raman emission feature at $\lambda\lambda 6825$, which is not present in FBS0107; this could be due to FBS0107 having not yet developed a high excitation emission line spectrum.

The photometry of FBS0107 raises two difficulties with the symbiotic nova interpretation. The first is the almost total lack of variability, at least by symbiotic star standards. All symbiotic systems (including symbiotic novae) seem to have significant photometric variability on many time scales, with many different origins (e.g. Skopal 2003), while conspicuous variability seems to be missing in FBS0107. The second issue concerns the time scale of the conjectured FBS0107 outburst. The slowest symbiotic nova, AG Peg, has a mean decline of 2.3 mag per century (Kenyon 1986). We cannot rule out the possibility that the 1951-54 Palomar Schmidt exposures were acquired during a separate earlier outburst. But if FBS0107 has remained bright since 1951-54, then the decline was only $\lesssim 0.3$ mag over 50 years. If FBS0107 is indeed a symbiotic nova in a prolonged outburst, then this outburst is extremely slow and the photometric stability during outburst is very high.

4.2. Other Possibilities

The optical emission lines in FBS0107 resemble that of a high N_e planetary nebulae (PN), as is true for many symbiotics. However, compared to the template PN spectra in Munari & Zwitter (2002), the ratios Balmer / [OIII] and [OIII]/[OI] are each much larger in FBS0107 than in a PN.

Gutiérrez-Moreno, Moreno & Cortes (1995) provide a diagnostic diagram to separate PN from symbiotic stars, using the line ratios $R1 = [\text{OIII}]4363/\text{H}\gamma$ vs $R2 = [\text{OIII}]5007/\text{H}\beta$. The [OIII] line strengths are ratioed to a nearby Balmer line partly to minimize the effects of differential extinction, which varies slowly with wavelength. In our case it is also important to use such ratios because they are nearly independent of the spectrophotometric calibration. This unknown calibration, which is normally critical in using emission line ratios for quantitative purposes, is also slowly varying with wavelength. Therefore we should still be able to apply R1 and R2 to FBS0107. Note that it is not safe for us to use the ratio $R3 = [\text{OIII}]5007/[\text{OIII}]4363$ as described in Gutiérrez-Moreno et al. (1995) because of the larger wavelength separation of the two features.

Gutiérrez-Moreno et al. (1995) find that in a plot of R1 vs R2 (their Figure 1) the region divides into 3 wedges emanating from the origin. The lower wedge (Region A) contains only PN, while the upper wedge (Region C) contains only symbiotic stars. The middle wedge (Region B) is lightly populated with young PN. From Table 3 we find $R1 = 0.06$ and $R2 = 0.36$ for FBS-0107. This point falls very close to the origin of the diagnostic diagram, in a region where the demarcation wedges are converging and there are very few objects. This is because the Balmer lines in FBS0107 are very strong compared to [OIII], pushing the values of R1 and R2 to very small values. It is the normalization process using nearby Balmer lines (which we need to retain) that is causing the difficulty; the ratio of the two [OIII] lines is the important variable, and that ratio is within range of the plot. Therefore we characterize the two dividing lines for the three wedges as $R4 \equiv R1/R2 = 0.17$ for the upper line and $R4 = 0.075$ for the lower line. For FBS0107, $R4 = 0.17$. This places FBS0107 on the dividing line between symbiotics and young PN, and quite some distance from the wedge containing PN.

A major difficulty in associating FBS0107 with PN is that the photospheric features in FBS0107 are not that of a PN central star (hot subdwarf), but rather of an early F giant. Furthermore we detect no nebulosity around FBS0107.

B[e] stars (Zickgraf 1998) are early-type emission line stars with low-excitation permitted and forbidden emission lines, plus the IR signature of hot dust. They have similarities to both symbiotic stars and to compact PN. As in symbiotics, the group is not homogeneous and may represent more of a common phenomenon than a group having a common physical nature.

Unlike symbiotics, they are not required to have a composite spectrum, and may mostly be single stars. The observational similarities between B[e] stars and symbiotic binaries in outburst are strong because the M star in symbiotics is often hidden from view during eruption. It seems likely that there is cross-contamination between lists of symbiotics and B[e] stars, awaiting clarification based on the binary nature of the object.

B[e] stars are mostly B stars, so the late A/early F spectrum in FBS0107 is not a good fit to the B[e] grouping. Another distinction may be between the “hot dust” in B[e] stars and the cooler dust in D type symbiotic stars. The 2MASS colors of FBS0107 are $J-H = 0.27$ and $H-K_S = 0.65$. Gummersbach et al. (1995) show the location of B[e] stars in the two-color diagram $J-H$ vs $H-K$. (The difference between $H-K$ and $H-K_S$ (Carpenter 2001) is unimportant for our purposes.) FBS0107 falls just outside the blue edge (in both colors) of the B[e] star grouping, which is an inconclusive result.

Finally, one other object in the Kopylov et al. (1988) list has similarities to FBS0107. This object (FBS0022-021 = Psc 3) has a blue continuum and numerous emission lines, some being forbidden. Zharikov et al. (2004) suggested that this might be an η Car-type object, partly due to the Fe-rich nature of the spectrum. However, unlike FBS0022-021, the Fe lines in FBS0107 are not particularly strong or numerous.

5. Conclusions

Although our conclusion is not as rugged as desired, our opinion is that FBS0107 is most likely a symbiotic nova, seen in prolonged outburst. This judgement is partly due to the shortcomings of various competing identifications, but is mostly based on the presence of the early-F photosphere in the spectrum of FBS0107. The presence of this absorption spectrum is quite secure and is difficult to explain without invoking the outburst phase of a nova event. The fact that FBS0107 deviates somewhat from the properties of most symbiotic stars insofar as IR colors and emission line ratios is tentatively attributed to the fact that FBS0107 is in prolonged outburst, and therefore not representative of the majority of symbiotic binaries which are found in quiescence. A somewhat worrisome implication of our interpretation is that FBS0107 must be an extreme member of the small class of symbiotic novae, having an outburst time scale perhaps as long as that of AG Peg, and changing so slowly at present that photometric variations are barely detectable.

Symbiotic binaries have been considered as progenitors of Type Ia supernovae (e.g. Munari & Renzini 1982; Kenyon et al. 1993; Hachisu et al. 1999), especially the subclasses of recurrent novae (Mikolajewska 2008) and symbiotic novae, (e.g. Hernanz & José 2008). Note

however that there are considered arguments against symbiotic binaries being a significant channel for SNIa (e.g. Hillebrandt & Niemeyer 2000; Iben & Fujimoto 2008). In any case, this aspect of symbiotic binaries may lend additional motivation to understanding the nature of FBS0107, especially if FBS0107 is able to remain in very protracted thermonuclear outburst, as we are suggesting.

Fortunately our symbiotic outburst hypothesis has fairly straightforward tests. If FBS0107 is currently in symbiotic outburst, then photographic plate archives may provide a record of the pre-outburst state. Also, narrow-band imaging at high angular resolution may reveal nebulosity. Non-optical observations can further discriminate among the possible candidates for the nature of FBS0107; for example, it would be most interesting to know if FBS0107 is (or has been) a supersoft x-ray source, indicative of steady nuclear burning. Overall, it seems that one of our more definite conclusions is the all-too-common ending to observational papers that “more observations are needed”.

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Table 1. Photometry Log

Set	UT Range	Tel	Exp time	# Exps	Dur	Spacing
1	2005-Nov-17	Tenagra	95s	96	6.0 hr	140s
2	2005-Nov-21	Tenagra	95s	202	5.1 hr	140s
3	2005-Nov-05 to 2005-Dec-22	Tenagra	95s	37	45d	1-2d
4	2007-Aug-08 to 2009-Jan-02	IN 1.25-m	240s	122	514d	2-4d

Table 2. Spectroscopy Log

UT Date	Tel	Range(\AA)	Exp time(s)	# Exps
2004-Aug-27	ESO 3.6-m	3450-5240	600	5
2004-Aug-27	ESO 3.6-m	4700-6700	600	18
2005-Oct-25	WIYN 3.5-m	5300-8200	600	5
2006-Jan-03	KPNO 4-m	5600-7900	600	1

Table 3. Equivalent Widths of Lines in FBS 0107-082

Line	ESO-blue	ESO-red	WIYN	KPNO
H8	-4.8	...	...	...
CaII 3934	+0.9	...	...	...
H ϵ	-3.9	...	...	...
HeII 4026	-1.4	...	...	...
H δ	-8.0	...	...	...
H γ	-16.1	...	...	...
[OIII] 4363	-1.0	...	...	...
HeI 4388	-1.0	...	...	...
[FeII] 4414	-0.7	...	...	...
HeI 4471	-2.5	...	...	...
HeII 4686	-3.6	...	...	...
HeI 4713	-1.3	...	...	...
H β	-56.9	-60.0	...	...
HeI 4922	-2.4	-3.4	...	...
[OIII] 4959	-6.7	-7.4	...	...
[OIII] 5007	-19.6	-21.7	...	...
HeI 5015	-2.9	-4.2	...	...
HeI 5876	...	-9.9	-8.3	-8.6
NaD1 5890	...	+0.6	+0.3	+0.8
NaD2 5896	...	+0.5	+0.4	+0.4
FeI 6164	...	-1.9	-1.9	-2.3
[OI] 6300	...	-1.5	-1.2	-1.3
H α	...	-453	-402	-424
HeI 6678	...	-5.4	-3.9	-1.8
HeI 7065	...	...	-6.0	-6.6
HeI 7281	...	...	-1.9	-2.0
OI 7772	...	...	+1.2	+1.2

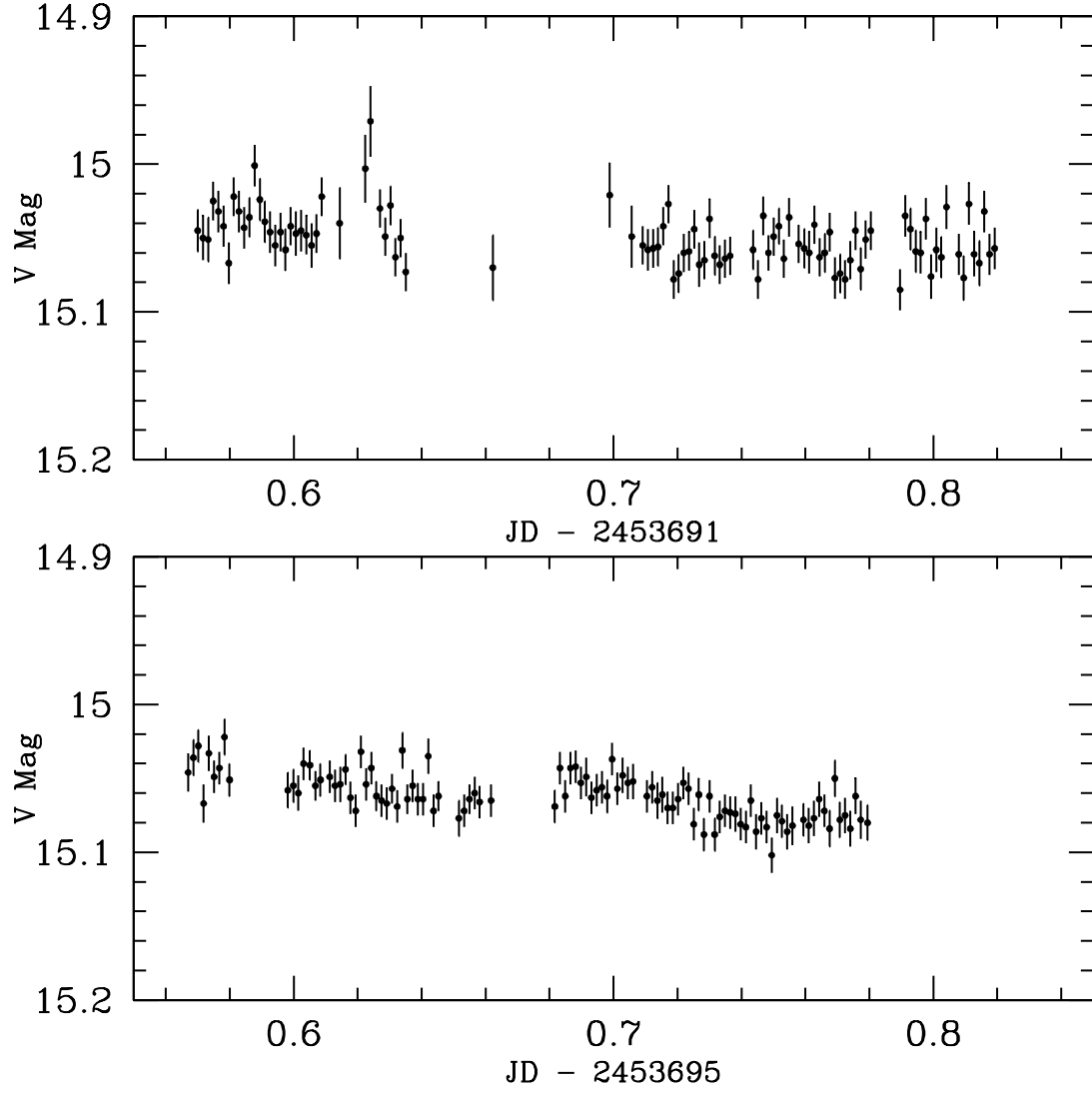


Fig. 1.— Photometric sequences of FBS0107 on two nights in 2005. These are plots of Data sets 1 and 2 in Table 1.

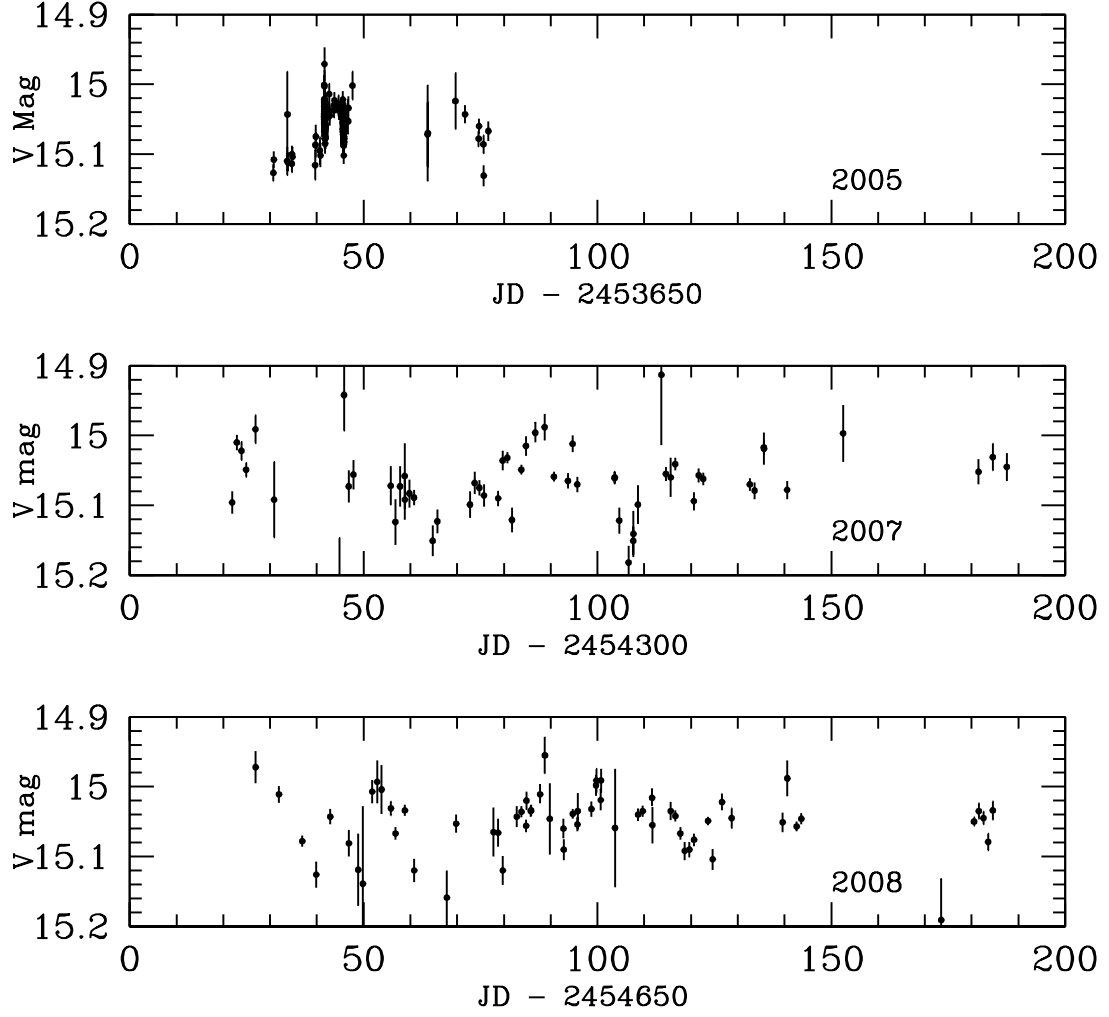


Fig. 2.— Top panel: photometry of FBS-0107 over 1.5 months in 2005. These are plots of Data sets 1, 2, and 3 in Table 1. Middle panel: photometry of FBS0107 over 1 season in 2007, which is part of Data set 4 in Table 1. Lower panel: photometry of FBS0107 over 1 season in 2008, which is also part of Data set 4 in Table 1.

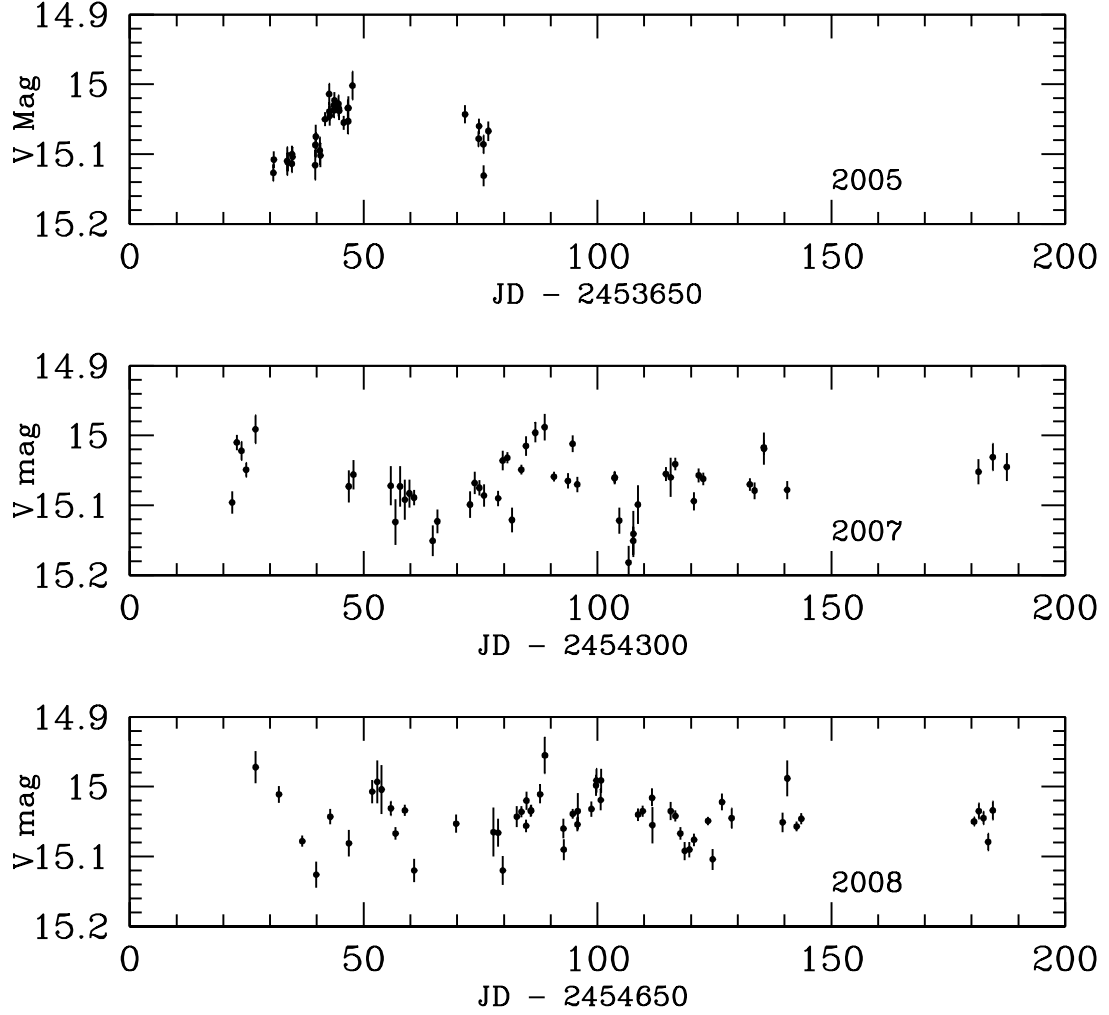


Fig. 3.— Like Figure 2 except that points with errors exceeding 0.035 mag have been deleted, and the single-night sequences (Data sets 1 and 2 in Table 1) have been replaced by single mean points. The remaining points show more clearly a number of systematic changes in brightness that occur over intervals of a few weeks.

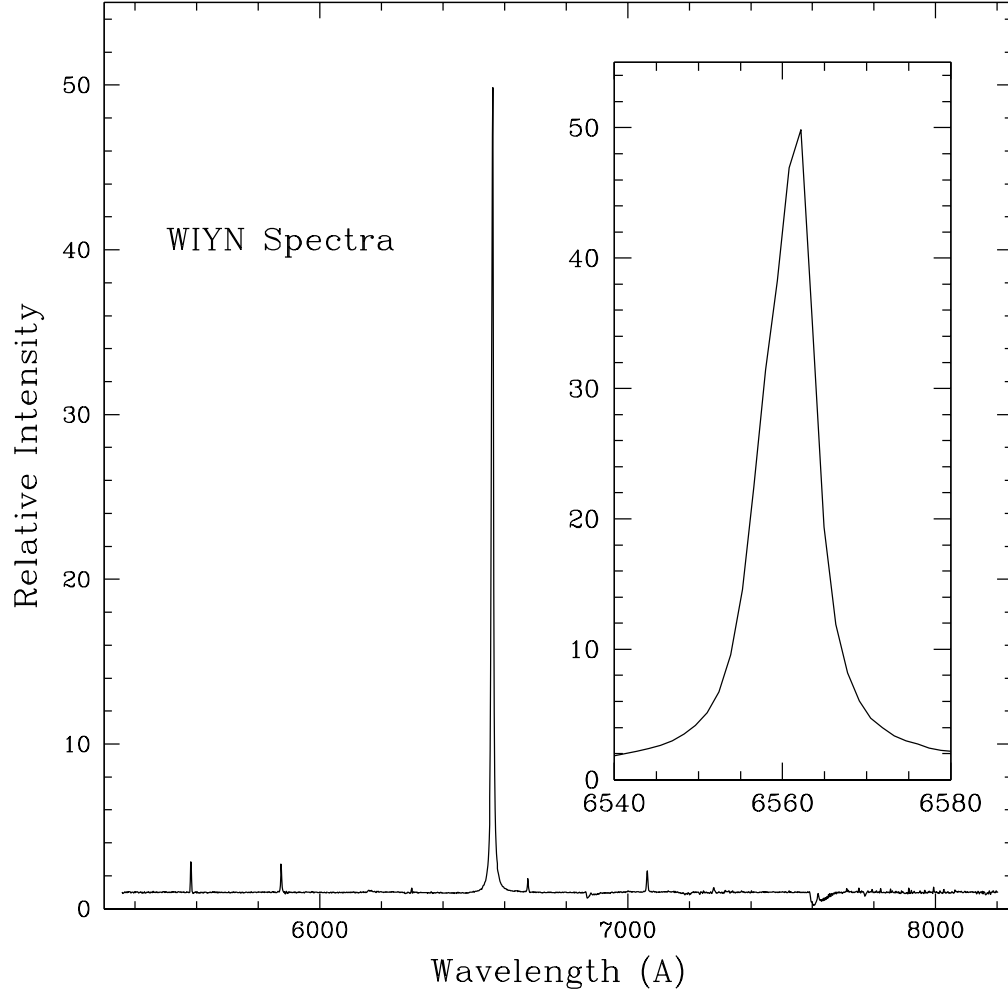


Fig. 4.— Average of 5 WIYN exps of FBS 0107-082 on 2005-Oct-25 UT. There has been no correction for telluric absorption features. Also the correction for sky emission lines is incomplete. This has left some residual OH emission features redward of 7700Å and some unknown contribution of night sky [OI] 5577 to the HeI 5582 line. The continuum is normalized to unity, and the inset shows H α on an expanded scale

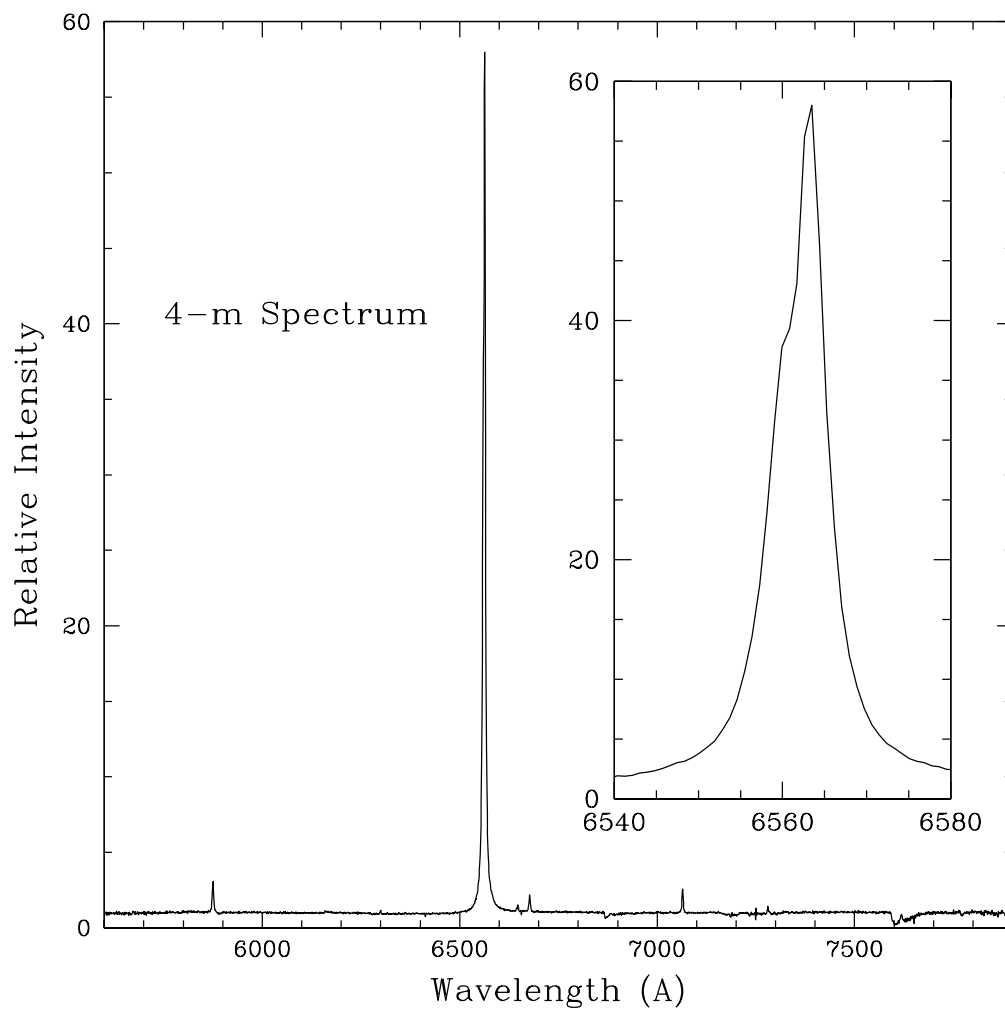


Fig. 5.— Spectrum of FBS 0107-082 on 2006-Jan-03 UT using the KNPO 4-m. There has been no correction for telluric absorption features. The continuum is normalized to unity, and the inset shows H α on an expanded scale.

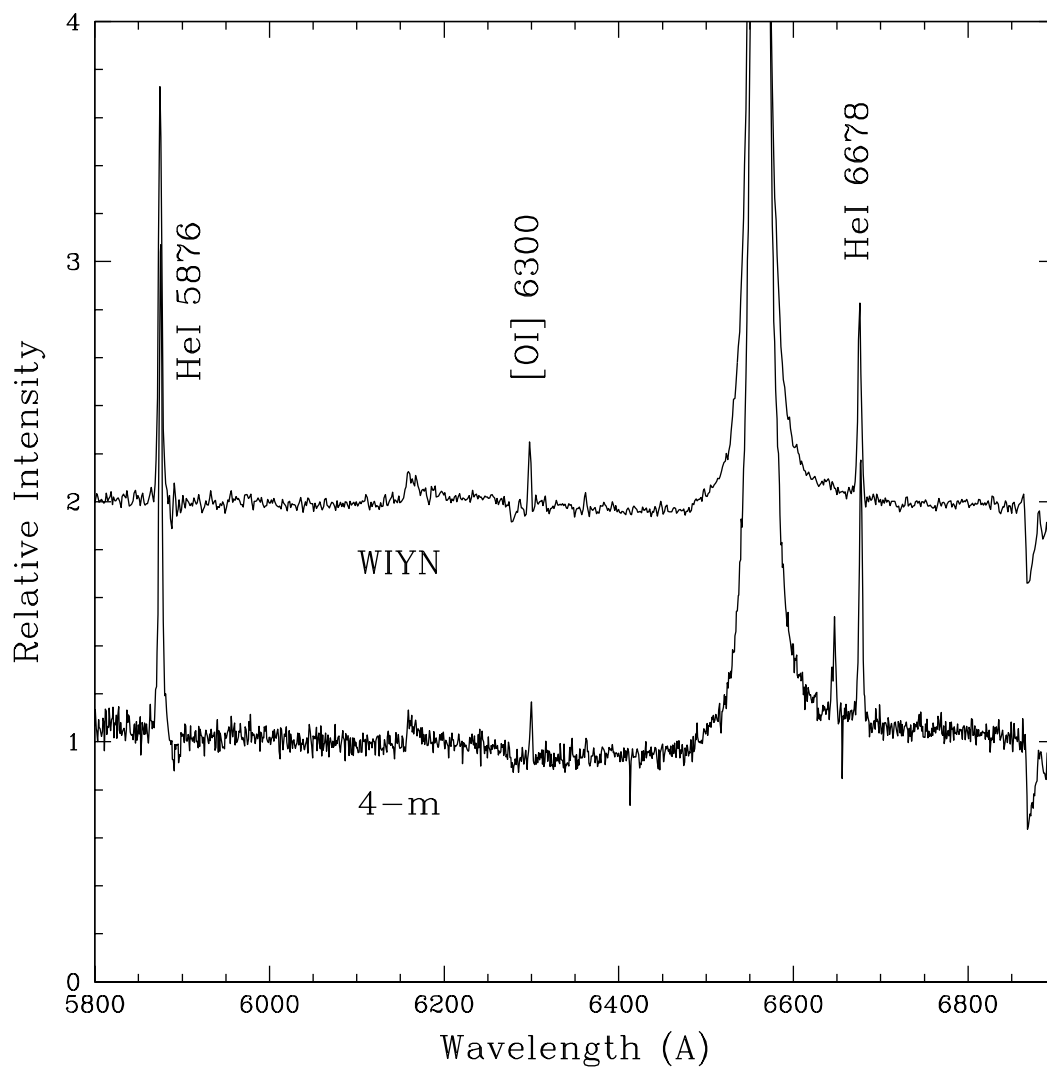


Fig. 6.— The blue portions of the data in Figures 4 and 5, plotted for the wavelengths in common and using an expanded intensity scale to emphasize the weaker features. The apparent emission line near 6650Å in the 4-m spectrum is an artifact.

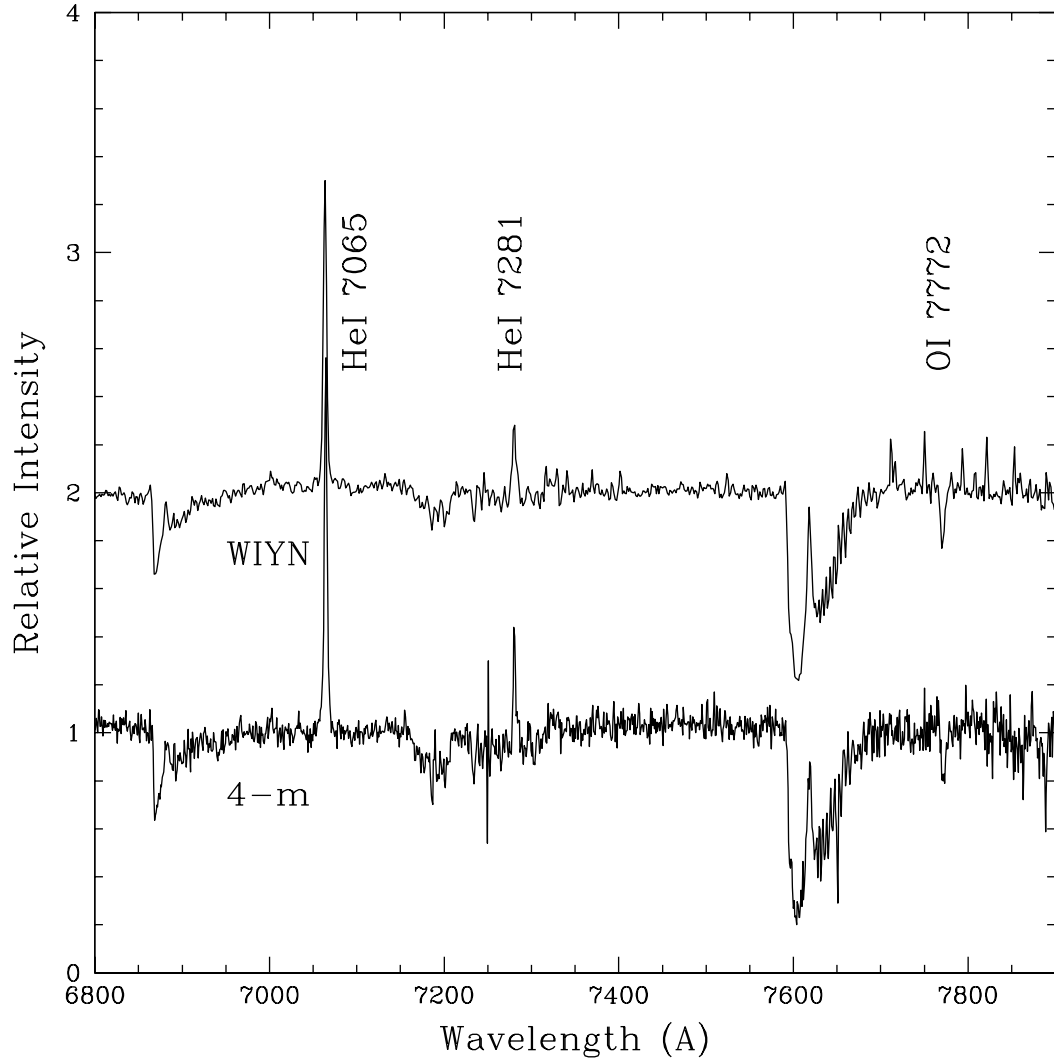


Fig. 7.— The red portions of the data in Figures 4 and 5, plotted for the wavelengths in common and using an expanded intensity scale to emphasize the weaker features. Broad telluric absorption is seen near 7190 and 7620Å.

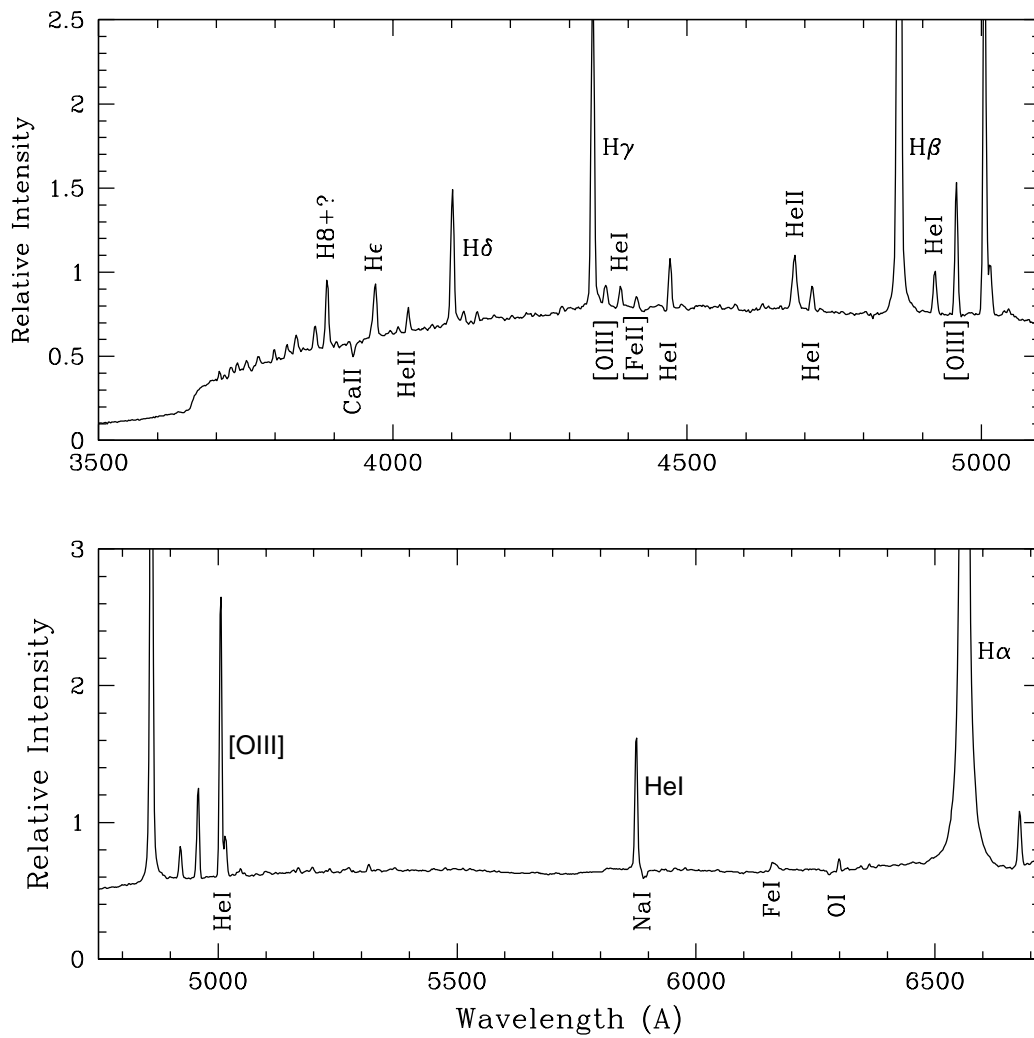


Fig. 8.— The 2004 ESO spectra of FBS0107, dominated by Balmer emission, He lines, and nebular lines of O and Fe.

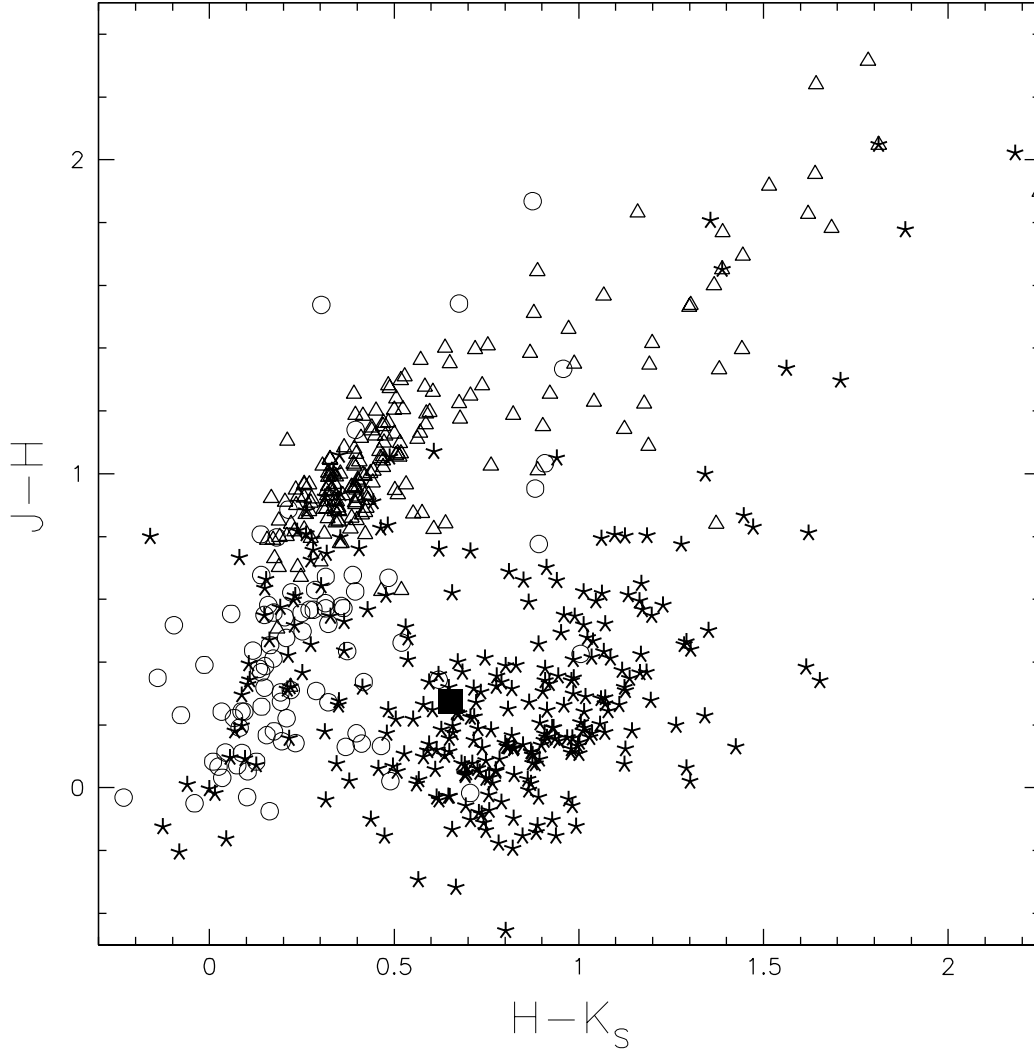


Fig. 9.— 2MASS color-color plot of CVs (open circles), planetary nebula (stars), and symbiotic stars (open triangles). The location of FBS0107 is indicated by a large filled square. Although FBS0107 has many of the optical spectral characteristics of symbiotic stars, its near-IR colors place in the region occupied by planetary nebulae.